TREE SPECIES-SOIL RELATIONSHIPS ON MARGINAL SOYBEAN LANDS IN THE MISSISSIPPI DELTA[1]

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Abstract—In the Mississippi Alluvial Plain, marginal soybean lands are those lands that are frequently flooded and have relatively low average soybean yields. These marginal farmlands might be regenerated to bottomland hardwood species if species-site relationships and silvicultural systems were better developed. Cost effective establishment and management of these stands will require an understanding of species-soil compatibility as well as an appreciation of the impacts of long-term soybean cropping on this relationship. Published site selection systems are evaluated within the context of afforestation on marginal soybean land in the Delta. Projected site indices and species-site suitability is given for former soybean lands on soil series that are marginal for soybean production. Potential improvements in species-site selection methods for soybean land afforestation are discussed.

INTRODUCTION

Soybean price increases during the 1970's resulted in a large amount of cleared land in the lower Mississippi Valley (Delta) (Sternitzke 1976). Some of this land is now apparently of marginal value for agriculture. In 1996, a consortium of industry, conservation and economic development agencies sought to evaluate the potential of these lands to enhance the economic and environmental integrity of the region (Amacher and others 1998). While the relative costs and benefits of soybean agriculture are well known for these lands, productive potential following reforestation remains poorly understood. Landowners, forest industry and government agencies would benefit from knowing the productivity of afforested former soybean lands to aid in land use decisions, regionwide raw material projections and development of reforestation incentive programs. Guidelines making site-specific species recommendations and productivity predictions would be most useful toward these ends.

To date, three published systems are available for matching species with site for reforestation efforts:

1. Broadfoot (1976) provides specific species recommendations and estimates a range of productivity for a limited number of soil series in the mid-south region.
2. County soil surveys are widely available in this region. The newer editions include estimates of forest productivity and recommend tree species for planting by soil series. However, these estimates are based on limited data and may be unreliable.
3. Baker and Broadfoot (1979) predict site index for several bottomland hardwood species by evaluating soil and site attributes. In the past, use of this system required intensive sampling of the planting site. However, recent county soil surveys now include necessary information and soil mapping of the region is virtually complete. In the case of former soybean lands, soil survey data combined with assumptions regarding soil and site attributes can be made permitting generic modeling of potential productivity for soil series.

The objectives of this study were to evaluate tree species-soil productivity guides to make species selection and predict potential productivity for several soil series representative of marginal soybean lands. Improvements are suggested for the further development of species selection and productivity estimation tools for old fields.

METHODS

Selection of Soils for Consideration

The study area was limited to counties located entirely or partially within the Delta in the states of Arkansas, Louisiana and Mississippi (fig. 1). Ten Delta soil series were selected for study according to the following criteria:

1. Soybean cultivation is commonly practiced.
2. Soils are poorly or somewhat poorly drained.
3. Flooding frequency ranges from occasional to frequent.
4. Soils are classified as hydric.

All soils used in this study met each of these criteria except the Dundee series, which is not hydric but often occurs in close association with several of the other soil series (Soil Conservation Service 1987). Tree species were selected for evaluation on the basis of potential to occupy bottomland sites and eventual merchantability.

Site Productivity Estimates

Estimated site productivity was calculated using the methodology developed by Baker and Broadfoot (1979). This system involves assigning point values for several soil and site criteria. For each criterion, point values are assigned in accordance with its relative importance to the growth of a particular species. When values have been assigned for each criterion, point values are summed to provide an estimate of site index for the given species and site conditions. In order to make generic estimates for economically-marginal soybean fields, several assumptions were made (table 1). In this way, species productivity estimates could be made for each soil series entirely on the basis of information available in published soil surveys. This evaluation eliminates the costs associated with on-site soil

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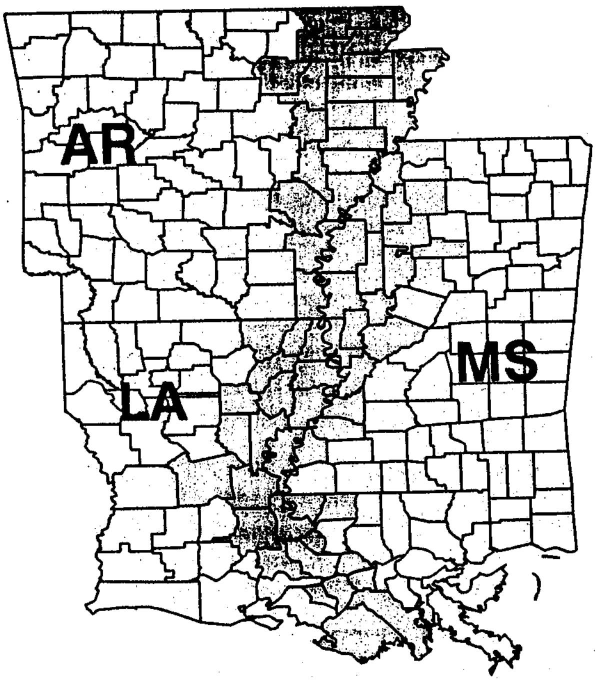

Figure 1 - Counties included in acreage estimates for soils of potentially marginal productivity for soybeans.

and site evaluation, but also may sacrifice the accuracy of these direct determinations.

RESULTS

The Soil Resource

Ten soil series meeting the established criteria cover nearly 30 percent of the Delta with Sharkey soils by far the most prevalent region wide (table 2). While current information is not available regarding the exact proportion of each of these soils in soybeans, forest, abandoned and other land uses, large portions of each of these series have been cleared for agricultural purposes. For example, the soil survey for Coahoma County, Mississippi indicated in excess of 90 percent of most selected soil series were in cultivation. Total acreage represented by selected soil series are in excess of two million acres in each of the target states for a total of greater than 7.5 million acres across the three state region.

Estimated Productivity

Cottonwood (*Populus deltoides* Bartr. ex Marsh.) tended to have high estimated productivity values on silty soils with Nuttall oak (*Quercus nuttalli* Palmer) projected to have the highest site indices on less productive clay soils, a trend generally consistent with Broadfoot (1976) and soil surveys based on non-agricultural soils (tables 3 and 4). Two of the tree species considered, Nuttall oak and green ash (*Fraxinus pennsylvanica* Marsh.), were determined to be appropriate for afforestation of former soybean fields using Baker and Broadfoot (1979) criteria, regardless of soil series (table 3). Sycamore (*Platanus occidentalis* L.), sweetgum (*Liquidambar styraciflua* L.), swamp chestnut oak (*Q.*

Table 1—Criteria used by Baker and Broadfoot (1979) for site evaluation in bottomland hardwoods and assumptions used in this study. Values for soil type-dependent variables (SD) were obtained from soil surveys and are shown in table 2

Criterion	Source of information/assumption
Soil depth	County soil survey (all soils are deep)
Presence of a pan	County soil survey (no soils have an inherent pan, assume deep plowing to disrupt plow pans)
Soil texture	County soil survey
Soil compaction	County soil survey
Soil structure	County soil survey
Past use and cultivation	Assume more than 20 years continuous
Present cover	Assume soybean cultivation is the equivalent of annual fertilization
Water table depth	County soil survey
Topographic position	All sites are floodplain
Microsite	Assume all microsites are flat due to leveling associated with cultivation
Flooding	Soil Conservation Service 1987; County soil survey
Geologic origin	Mississippi River alluvium
Organic matter content	Assume less than one percent due to repeated cultivation
Depth of topsoil	County soil survey
Soil age	County soil survey
pH in rooting zone	County soil survey
Swampiness	County soil survey
Depth to mottling	County soil survey
Soil color	County soil survey

Table 2—Soil series with some or all phases considered marginal for soybean production in the Mississippi Alluvial Plain of Arkansas, Louisiana and Mississippi

Series	Percent of Delta region	Area (thousands of acres)		
		Arkansas	Louisiana	Mississippi
Alligator	4.9	229	280	739
Amagon	.8	209	0	0
Bowdre	.3	52	0	31
Dundee	4.0	315	238	461
Forestdale	2.5	81	55	484
Mhoon	.6	92	48	3
Newellton	.4	58	43	5
Sharkey	13.9	1,080	1,660	781
Tensas	1.2	0	292	0
Tunica	1.2	91	105	95
Total	29.8	2,207	2,721	2,599

Table 3—Site index predictions based on Baker and Broadfoot (1979) for seven hardwood tree species for soil series likely to support marginal soybean agriculture in the lower Mississippi Valley. Missing values indicate species-soil combinations projected to be too low for further management (Baker and Broadfoot 1979)

Series	Green ash	Nuttall oak	Sycamore	Sweetgum	Swamp chestnut oak	Water oak	Cotton-wood
Alligator	74	80	75	78	66	—[a]	—
Amagon	76	83	82	82	73	77	89
Bowdre	74	77	71	78	65	71	—
Dundee	79	83	82	88	72	80	91
Forestdale	71	76	—	—	—	—	—
Mhoon	78	82	71	76	68	—	92
Newellton	77	81	76	81	66	72	80
Sharkey	72	78	70	75	66	70	—
Tensas	73	79	70	76	66	72	—
Tunica	71	77	—	—	—	—	—

[a] No data.

michauxii Nutt.) and water oak (*Q. nigra* L.) were projected to be suitable for all but the less productive series among the clay soils. Cottonwood was projected to be suitable for the silty soils as well as Mhoon and Newellton series, two of the more productive clay textured series.

Projected site indices for marginal soybean lands were consistently lower than estimates published in soil surveys with discrepancies typically ranging between 10 and 20 percent (table 4). Estimates calculated for soybean fields were typically below or near the lower extreme of Broadfoot (1976) for soil series where these estimates were made.

Green ash differed least between estimates based on agricultural and non-agricultural soils.

DISCUSSION

Differences between soil survey values and our estimates based on Baker and Broadfoot (1979) may reflect differences in assumptions made in forest conditions. Estimates made by Broadfoot (1977) and those incorporated in soil surveys assume natural regeneration of natural, well-stocked stands with no evidence of cutting or burning. Our assumptions using the Baker and Broadfoot (1979) guide incorporated likely changes in soil and site condition

Table 4—Estimates of soil productivity for selected species on ten soil series in the Mississippi Alluvial Plain

Series	Species	Soil survey average	Broadfoot (1976) range	Baker and Broadfoot (1976) estimate for former soybean lands	Percent difference Baker and Broadfoot (1979) and soil survey
Alligator	Cottonwood	90	80-100	76	-16
	Green ash	70	70-90	74	+6
	Sweetgum	80	75-95	78	-3
	Water oak	90	75-95	72	-20
Amagon	Cottonwood	100	NA	89	-11
	Green ash	80	NA	76	-5
	Nuttall oak	100	NA	83	-17
	Sweetgum	100	NA	82	-18
	Water oak	100	NA	77	-23
Bowdre	Cottonwood	110	NA	73	-34
	Sweetgum	95	NA	78	-18
	Water oak	95	NA	71	-25
Dundee	Cottonwood	100	90-110	91	-9
	Sweetgum	100	90-110	88	-12
	Water oak	95	85-105	80	-16
Forestdale	Cottonwood	100	85-105	79	-21
	Green ash	78	70-90	71	-9
	Nuttall oak	95	80-100	76	-20
	Sweetgum	95	85-105	71	-25
	Water oak	90	80-100	65	-28
Mhoon	Cottonwood	110	NA	92	-16
	Green ash	90	NA	78	-13
	Sweetgum	100	NA	76	-24
Newellton	Cottonwood	100	105-125	80	-20
	Green ash	75	70-90	77	+3
	Nuttall oak	85	90-110	81	-5
	Sweetgum	95	90-110	81	-15
	Water oak	90	80-100	72	-20
Sharkey	Sweetgum	90	80-100	75	-17
	Water oak	90	80-100	70	-22
Tensas	Sweetgum	100	90-110	76	-24
	Water oak	95	85-105	72	-24
Tunica	Cottonwood	90	90-110	75	-17
	Sweetgum	90	85-105	73	-19

NA = not available.

associated with long-term row crop cultivation. Given the constraints of this project, it has not been possible to validate these estimates.

Agricultural soils are characterized by higher bulk density, presence of a plowpan, lower soil organic matter, altered fertility and smaller available rooting volume due to the presence of plowpans (Francis 1985; Stanturf and others, in press). However, the shrink-swell clay mineralogy and previous agricultural amendments may counteract these potential limitations. Several practices including weed control treatments, fertilizer applications, fallowing and deep plowing have been recommended to ameliorate the adverse effects of long-term agronomic practices (Baker and Blackmon 1978; Blackmon and White 1972; Francis 1985) and may largely overcome these limitations on former agricultural lands.

Over the past several decades, silviculturists and soil scientists have sought to improve forest regeneration success and increase yields of bottomland species. Most of this work has involved regeneration of recently cutover lands with less emphasis on afforestation of old fields. Changes in site and soil properties resulting from agriculture make extrapolation from cutover lands to marginal soybean fields difficult. Growth and yield data have not been published for hardwood stands established on old fields for at least two reasons. 1. Most stands are not well enough developed to yield reliable long-term yield data, 2. No database or survey has been published compiling growth and yield data from existing stands.

Virtually all of the published information describing conditions and making recommendations for Delta old fields is restricted to the seedling establishment phase (Allen and

Kennedy 1989; Bullard and others 1992; Kennedy 1992). The lack of information from old field stands allowing the direct projection of rotation age yield estimates restricts us to the use of relatively speculative estimates used here. Several questions need to be addressed to quantify and increase productivity and regeneration success rate of forest stands established on old fields:

1. Does deep plowing improve productivity of hardwood plantations on soils with a large component of 2:1 clays? An informal comparison of deep plowed versus unplowed soils suggests that second year survival is not enhanced by this practice due to drying of the roots associated with soil shrinkage (Miwa, personal observation). Further, deep plowing may fail to break plowpans because of incomplete drying and the shrink and swell action of 2:1 clay soils, negating any long term benefits.
2. How do soil series differ in terms of the impact of long term agriculture on forest productivity potential?
3. Are the shapes of growth and yield curves affected by cultivation on old field sites? Also, a base age of 25 years for site index determinations may be desirable since utilization of smaller stems will shorten rotation lengths.
4. What intermediate treatments will be required to maximize productivity of various product size classes?
5. What is the economic feasibility of using nurse crops to enhance soil properties and improve tree form (McKevlin 1992)?
6. Guidelines for the establishment and management of Delta old fields should be revised incorporating recent improvements in hardwood cultivation techniques and changing product objectives. For example, cottonwood productivity on Sharkey soils may be adequate for pulpwood management if rotation lengths are shortened. Cooperation in this effort among government, industry and academic researchers and land managers would strengthen this effort.

CONCLUSIONS AND RECOMMENDATIONS

Evaluation of soil survey data using Baker and Broadfoot (1979) suggests that published values overestimate hardwood species productivity for old field sites and could lead to inappropriate species selections if soil survey recommendations are followed. It is critical to recognize that values and recommendations are based entirely on published guidelines. These values are not intended to serve as substitutes for the development of empirically based, region-specific guidelines for former agricultural fields. Rather, we hope these estimates will be used to further evaluate the relative importance of Baker and Broadfoot criteria in regenerated old field stands and help provide support for the development of the next generation of site selection and productivity estimators. Designed studies would complement the wealth of field observations and professional experience incorporated by Baker and Broadfoot and may correct widely observed overestimates of productivity resulting from the use of this method.

Improving the soil physical and chemical data provided in soil surveys as well as the nearly complete soils mapping of the region are a tremendous asset in implementing any multivariate species-site evaluation tool. However, further information is needed to account for frequency and duration of flooding and ponding. Changes in local hydrologic patterns due to the development of levee systems may also affect the species choice for a particular site. Local knowledge of past and current flooding regimes will help in making species selection recommendations for a specific site (Kennedy 1992). We suggest that a regionwide database of successful and failed old field plantings be developed to facilitate this process. Further, landowners would benefit from a revised compilation and synthesis of research results and anecdotal experience relating to forest establishment on economically marginal agricultural sites of the Delta.

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